Detection of Spontaneous Circulation during Cardiopulmonary Resuscitation using Continuous Carotid Artery Doppler Blood Flow monitored by AI in an Animal model of Cardiac Arrest

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Background

- Manual pulse palpation during cardiopulmonary resuscitation (CPR) to check for spontaneous circulation is often unreliable and time-consuming.
- We've developed RescueDoppler, a small ultrasound device that attaches to the neck to continuously monitor carotid artery blood flow. It provides automatic, real-time feedback to rescuers on the presence of spontaneous circulation.

Hypothesis

- AI can assist during CPR to detect the onset of spontaneous circulation

Aim

- To provide automatic feedback on spontaneous circulation during cardiac arrest in an animal model using advanced state-of-the-art deep-learning techniques.

Disclosures

- The RescueDoppler Project has received funding from the Norwegian Research Council and the Central Norway Regional Health Authority (RHA). Charlotte Björk Ingul serves as a Medical Advisor at Cimon Medical. Hans Torp is employed by Cimon Medical. All other authors have no conflicts of interest.

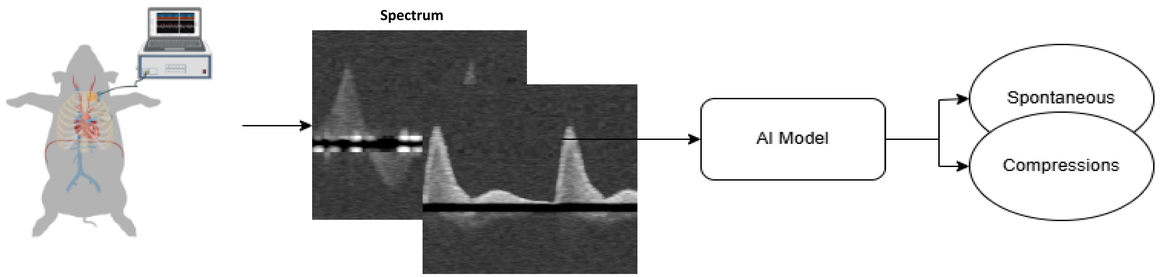
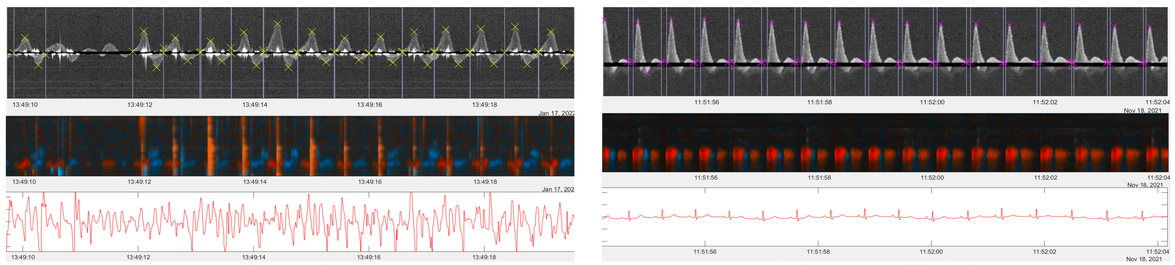


Figure 1: Approach employed for Spontaneous circulation detection



a. Compressions b. Spontaneous Circulation

Figure 2: The example images depict the annotations of compression and spontaneous circulation signals.

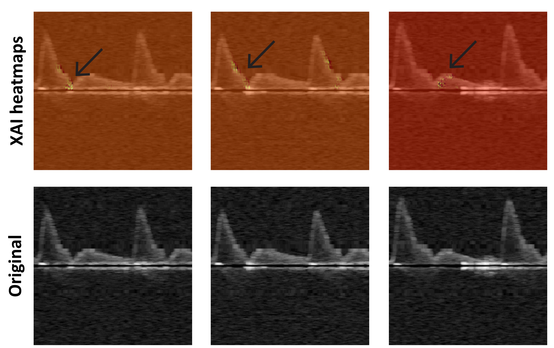


Figure 3: Explainable AI (XAI) heatmaps alongside the corresponding original image of spontaneous circulation.

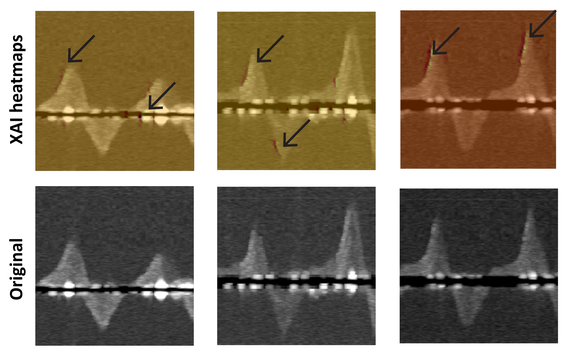


Figure 4: Explainable AI (XAI) heatmaps alongside the corresponding original image of compressioons.

Approach

- Conducted a retrospective study using deep learning for RescueDoppler carotid blood flow velocity spectrum from 5 pigs.

Methods

- **Data acquisition**: Ventricular fibrillation was induced with an implantable cardioverter-defibrillator. Manual chest compressions were performed according to guidelines. Blood flow velocities are recorded using RescueDoppler system.
- **Annotations:** Annotated pulsed wave spectral velocity curves using an in-house annotation tool. We annotated 2610 heart cycles and labelled them as compressions and spontaneous signals as shown in Fgure 2.
- **Dataset:** One second pulses are extracted from the recordings
- **Training:** A VGG16 pre-trained model was used as a feature extractor with a 2-class classification head, employing One-Vs-Rest cross-validation with one subject left out for testing in each fold.
- **Explainable AI:** Explainable AI aims to make AI model decisions transparent, helping users understand, trust, and interpret how and why predictions are made. We used Grad-CAM to visualize and interpret the model's decision-making.

Results

- Achieved mean sensitivity of 94%, specificity of 95%, positive predictive value (PPV)of 95%, and negative predictive value (NPV) of 93% across all folds.
- Explainable AI heatmaps (Figure 3 & 4) depicts the key features for compressions and spontaneous circulation.

Discussion

- Model is not biased towards specific subject/s
- Key features are diastolic flow and dicrotic notch for spontaneous and baseline noise, positive and negative slopes for compressions.

Conclusions

- In a porcine model of cardiac arrest, we demonstrated that deep learning techniques can harness the potential of AI to identify spontaneous circulation during CPR, achieving highly accurate results.

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